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A STUDY ON LIQUEFACTION SUSCEPTIBILITY OF FINE GRAINED SOIL IN JABALPUR CITY

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ABSTRACT

Liquefaction is the transformation of granular material from solid state in liquefied state, with a significant increase in pore water pressure until effective stress reaches to zero. This causes damage in the form of landslides and foundation failure. Soil liquefaction has drawn the attention of the world, after two mighty earthquakes of Alaska & Niigata in the year 1964. Initially, research on liquefaction was based on uniform clean sand, containing little or no fines, but many past earthquakes occurred in the areas containing 20% to 90% fines, this had broken the earlier myth. Thus, the role of fineness emerged as an important aspect, in liquefaction susceptibility and is being studied by researchers all around. But, the criterions developed by them are complex, time consuming and need expertise. So, here in this study an attempt has been made, to develop a simplified approach to study this phenomenon through Index properties.

Jabalpur is a fast developing city and multistory buildings are also emerging in the city now. On the other side, cases of liquefaction were also reported in the city during the earthquake of 22nd May, 1997. So, the knowledge about liquefaction susceptibility of the city, is the need of the time. In view of these facts, this study is undertaken in Jabalpur city.

This study is conducted in the City of Jabalpur, Madhya Pradesh, India ($23^0$09'57.8"N & $079^0$57'05.5"), which is expanding rapidly in all directions. Looking to this fact, twenty locations are selected randomly for taking samples of soil.

Sampling is done at two different depths at each location. The collected samples are tested in the Geotechnical Engineering laboratory of Jabalpur Engineering College for Liquid limit, Plastic limit, NMC, DFS, Sieve analysis, as per the relevant IS a code of practice.

Liquefaction susceptibility of soils of the study area is ascertained, on the basis of criteria suggested by Andrews& Martin (2000), popularly known as the Modified Chinese criteria

Liquefaction is an amazing phenomena and also a complex one, and its susceptibility cannot be predicted /analyzed just by one criteria, only. So, to verify and ascertain this, the same obtained results are then put up in another criteria, developed by Seed et al. (2003) known as: -Recommendations assessment of liquefiable soil types.

The results obtained from both the criteria's are compared with one another, and on the basis of this comparison a final conclusion has been drawn.

KEYWORDS: Liquefaction is an amazing phenomena, -Recommendations assessment of liquefiable soil types & Sampling is done at two different depths at each location

Original Article

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INTRODUCTION

Liquefaction susceptibility of a soil may be defined as its physical characteristic that determines, whether a soil is able to liquefy or not. Liquefaction susceptibility of a soil is not dependent on the level of shaking required to trigger liquefaction. Initial research on liquefaction was based on uniform clean sand containing little or no fines, but many past earthquakes like Haicheng (1975) and Tangshan (1976) earthquakes occurred in the areas containing 20% to 90% fines, broken the earlier myth. Wang studied the damages due to these earthquakes and showed that, even silty, silty with clay, sand with fines could liquefy 1994 Northridge, 1999 Adapazari and 1999 Chi-Chi earthquakes further exposed more data for liquefaction of sand with fine grained soil. These earthquakes also showed that, soil with a certain range of the parameters is prone to liquefaction under cyclic seismic forces with a definite range of seismic parameters. It has now been established that, practically all soils including sands, silts, clays, and gravels and their mixtures can liquefy depending upon the extent of the seismic and environmental factors.

Deltaic deposits typically consist of fine-grained overbank and floodplain sediments, in some instances, inter bedded with sandy soils. In regions of high seismic risk, the liquefaction susceptibility of these fine-grained soils is often a concern in the design of foundations. Although liquefaction susceptibility of sand and gravel has been investigated with an increased focus, the liquefaction potential and post-liquefaction behavior of fine grained soils such as silts has not been given the same level of emphasis. The commonly accepted practice to assess the liquefaction resistance of sandy soils is to use the empirical liquefaction resistance charts, that have been developed based on penetration resistance measurements obtained using the SPT or CPT methods. These charts are generally applicable for soils containing up to 35% fines passing the US Sieve No. 200 (0.074 mm size). In soils containing significant amounts of fines, the accepted practice is to use the "Chinese Criteria", that have been established based on index properties and grain size data.

As there are various soil and earthquake parameters responsible for liquefaction due to the complex nature of soil and earthquake force. So, to demarcate the zones for susceptibility of liquefaction, it becomes essential to identify the most significant characteristics, by a comprehensive approach to studying liquefaction phenomenon, specifically for sand with fines. The soil passing 50% or more from 75 micron sieve is known as fine grained soil. It may contain clay and silt both. Sometimes non-plastic clay sized grains coming from mines and quarry from the soil strata and makes soil liquefiable, as liquefaction susceptibility of silt is similar to that of sand, and dissimilar to that of clay. Here, the question is this at what clay content of a fine soil; it becomes liquefaction susceptible like a sand or soil or non-susceptible like clay. Thus the role of fines emerged as an important aspect in liquefaction susceptibility and is being studied by researchers all around. These researchers made many laboratories and empirical studies and developed so many methods and criteria. These are complex, time consuming and need expertise. So there is a need of a simple way to determine the liquefaction susceptibility of giving soil.

As it is well clear from the experiences all over the world, that studies to understand the liquefaction potential of any area/ property is of prime importance because of the possibility for injury and structural damage. Land owners, occupants, and institutions of public interest (Banks, LIC, Nagar –Nigam, Jabalpur Development Authority etc.) are the concerning agencies. The well-informed real estate buyer can obtain this data before making a purchase decision. Owners of existing property may want to consider liquefaction potential when building, remodeling, or selling property.

If the potential / susceptibility of the soil of an area are known then buildings located in a liquefaction susceptible /potential area can be saved. A well designed, well constructed building in a liquefaction prone area may suffer much less damage than an inadequately designed or poorly constructed building located over non-liquefiable soils.

MATERIALS AND METHODS

Jabalpur city is taken as the area of this study. This city is located in the central part of Madhya Pradesh on the bank of river Narmada (23009’57.8”N & 079057’05. 5” E) at an elevation of 411 meters.

Twenty locations as shown in Figure 1 were selected in the city for this study. Samples of soil were collected from different depths at each location. Analysis of the samples was undertaken for Index properties as per the relevant I.S code of practice.

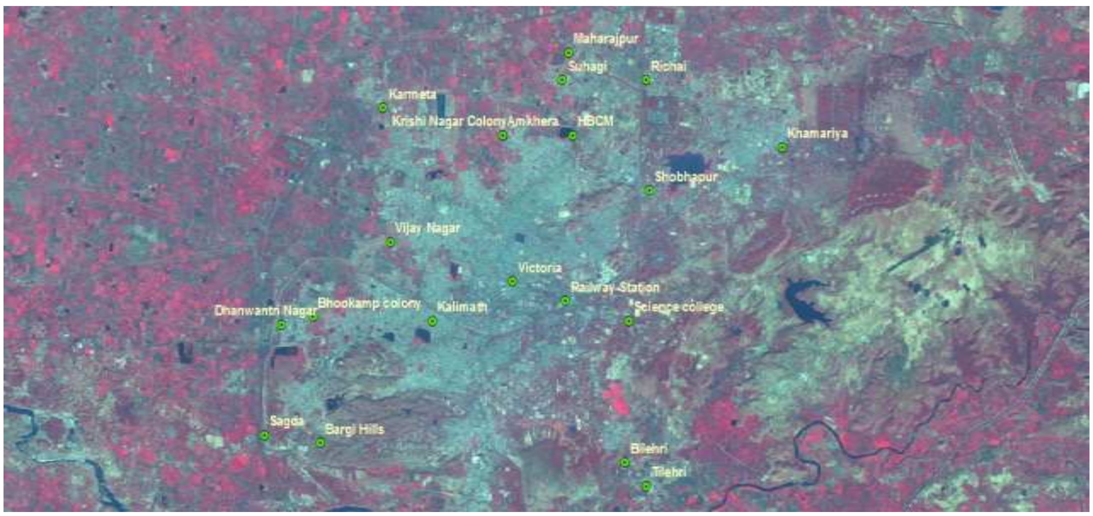

Figure 1: Map Showing the Sampling Stations

Table 1: Description of Sampling Stations

SI. No.	Location	Latitude	Longitude	Altitude (in ft)
1.	Housing Board colony Maharajpur	23012’29.5”	79057’14.1”	1254
2.	Maharajpur	23013’46.6”	79057’07.3”	1264
3.	Richai	23013’24.4”	79058’28.5”	1254
4.	Shobhapur	23011’40.2”	79058’30.7”	1256
5.	Khamariya	23012’19.8”	80000’50.3”	1316
6.	Science collage	23009’41.4”	79058’18.8”	1356
7.	Bilehri	2307’33.3”	79058’05.5”	1332
8.	Tilehri	2307’09.8”	79058’27.5”	1331
9.	Bargi hills	23007’50.5”	79052’54.7”	1367
10.	Sagda	23007’57.5”	79057’57.0”	1308
11.	Bhookamp colony	23009’45.0”	79052’45.2”	1271
12.	Dhanwantri Nagar	2309’36.1”	79052’45.2”	1268
13.	Kalimath	23009’43.1”	79054’48.3”	1274
14.	Railway station	23009’57.8”	79057’65.5”	1330
15.	Victoria	23010’18.2”	79056’9.7”	1301
16.	Vijay Nagar	23010’54.2”	79054’04.4”	1246
17.	Karrmeta	23012’54.9”	79053’57.6”	1235
18.	Amkhera	23012’29.9”	79056’00.0”	1238
19.	Krishi Nagar Colony	23012’30.0”	79055’59.9”	1209
20.	Suhagi	23013’19.4”	79057’00.9”	1246

Liquefaction susceptibility of soils of the study area was ascertained on the basis of criteria suggested by Andrews& Martin (2000), popularly known as the Modified Chinese criteria given below in Table 2 & Recommendations Assessment of Liquefiable soil types (Seed et al, 2003) given in Figure 2.

Table 2: Modified Chinese Criteria

	Liquid Limit < 32%	Liquid Limit ≥ 32%
Clay Content (< 0.002 mm) < 10%	Potentially Liquefiable	Further studies required considering plastic non-clay sized grains
Clay Content (< 0.002 mm) ≥ 10%	Further studies required considering non-plastic clay sized grains	Non-Liquefiable

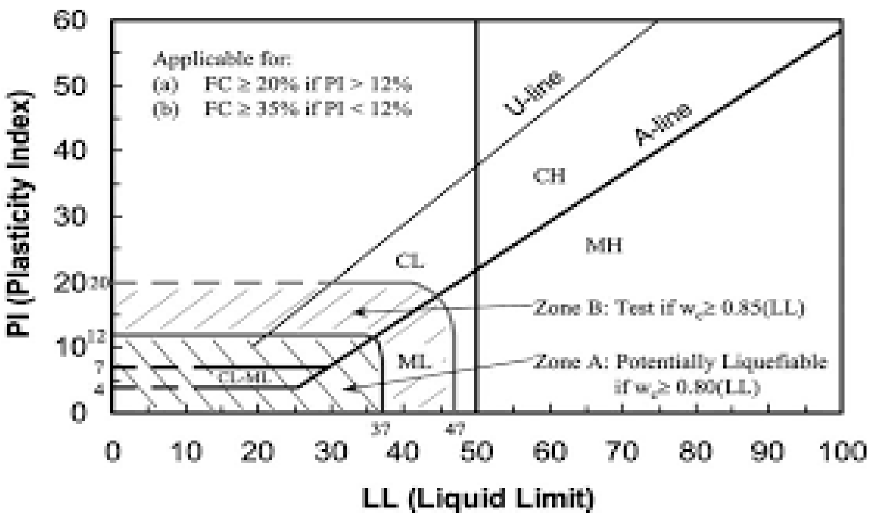

Figure 2: Recommendations Assessment of Liquefiable soil types (Seed et al, 2003)

Based on the two criteria, each sample was classified as susceptible/Not susceptible & further studies required.

RESULTS AND DISCUSSIONS

An attempt has been made to compare the susceptibility found through both the criteria for the same location. A table showing a comparison between both the criteria in ascertaining liquefaction susceptibility with the parameters governing the criteria is described/ mentioned below. This comparison is given under Table 2 (NS – Not susceptible, S- Susceptible, PSL- Potentially susceptible to liquefaction, PL- Potentially liquefiable, FSR- Further studies required)

It is clear on comparing both the criteria that, criteria No 1 (Seed et al. 2003) categorize a sample in 3 categories, IE 1. Potentially Susceptible to liquefaction, 2. Potentially liquefiable and 3. Not susceptible to liquefaction While the Modified Chinese criteria (Andrews & Martin, 2000); 1. Susceptible 2. Further studies required & 3. Not Susceptible. Thus, criteria no 1 (Seed et al., 2003) gives a clearer verdict about a sample while criteria no 2 (Andrews & Martin, 2003) recommend further studies of the sample.

It is clear from the table that, 28 samples out of 40 samples collected falls under the same category through both the criteria i.e. both approaches reach the same decision. On the other side samples of Maharajpur 4m, Kalimath 2m, Bargi

Hills 3m & Railway Station 2m falls, potentially susceptible to liquefaction from criteria no 1 while criteria no 2 declares these samples Not susceptible.

Similarly, cases of Science college 2m, Bargi Hills 2m Amkhera 3m are declared Potentially liquefiable, by criteria no 1, while criteria no 2 finds them susceptible to liquefaction. Samples of kalimath 2 & 3m depth both are put up in the group of potentially susceptible to liquefaction, by criteria no 1, but criteria no 2 says further studies are required.

Table 3

SI.No.	Location	Depth	Grain Size Distribution			Liquid Limit	Plasticity Index	SUS (CRIT 1)	Clay Content	SUS(CRIT 2)
			Gravel	Sand	Fines(-75μ)					
1.	Housing Board Colony Maharajpur	2m	0.658	6.622	92.72	50.75	27.714	NS	39%	NS
		3m	4.372	9.742	85.886	39.5	22.108	NS	36%	NS
2.	Maharajpur Basti	2m	1.355	25.71	72.935	46.5	28.14	NS	40%	NS
		3m	0.026	35.272	64.702	40.25	26.16	NS	35%	NS
		4m	0.558	56.077	43.365	29.1	14.55	PSL	18%	NS
3.	Richai	2m	1.532	6.436	92.032	57.15	32.543	NS	34%	NS
		3m	0.796	5.514	93.69	47.16	23.743	NS	32%	NS
4.	Shobhapur	2m	0.061	16.806	83.133	48.2	29.77	NS	40%	NS
		3m	0.485	19.505	80.01	46.78	19.01	PSL	39%	NS
5.	Khamariya	2m	0.34	8.37	91.29	42.325	20.485	PSL	39%	NS
		3m	0.158	2.614	97.228	46.35	24.051	NS	34%	NS
6.	Science College	2m	0	47.27	52.73	24.9	10.767	PL	9%	S
		3m	1.88	48.212	49.908	40.6	23.478	NS	17%	NS
7.	Bilehri	2m	1.336	7.614	91.05	60	29.26	NS	35%	NS
		3m	0.125	10.55	89.325	55	27.183	NS	33%	NS
8.	Tilehri	2m	0.204	2.896	96.9	57.8	40.63	NS	40%	NS
		3m	0	0.088	99.912	56.6	29.222	NS	34%	NS
9.	Bargi Hills	2m	9.572	36.176	54.252	30.6	08.119	PL	4%	NS
		3m	11.184	36.89	51.926	34.92	15.15	PSL	No clay	NS
10.	Sagda	2m	0.296	7.266	92.438	54.64	29.383	NS	31%	NS
		3m	5.044	14.562	80.394	55.01	33.205	NS	32%	NS
11.	Bhookamp Colony	2m	1.492	7.02	91.488	70.92	39.6709	NS	42%	NS
		3m	4.68	9.904	85.416	55.6	40.316	NS	36%	NS
12.	Dhanwantri Nagar	2m	0.112	5.502	94.386	64.22	32.477	NS	36%	NS
		3m	0.0984	3.0186	96.883	62.06	38.234	NS	32%	NS
13.	Kalimath	2m	1.702	47.498	50.8	27.9	19.698	PSL	15%	FSR
		3m	1.496	46.912	51.592	30.67	16.082	PSL	14%	FSR
14.	Railway Station	2m	0.146	40.393	59.461	35.9	18.73	PSL	32%	NS
15.	Victoria	2m	0.102	19.285	80.613	36.48	23.17	NS	17%	S
		3m	0.148	42.203	57.649	37.8	5.55	PL	9%	FSR
16.	Vijay Nagar	2m	1.077	7.866	91.064	56.47	30.211	NS	40%	NS
		3m	0.086	4.626	95.288	54.65	28.124	NS	38%	NS
17.	Karmeta	2m	1.632	9.839	88.529	58.03	33.12	NS	42%	NS
		3m	2.497	10.179	87.324	64.95	38.3659	NS	45%	NS
18.	Amkhera	2m	2.492	50.908	46.6	65	28.08	NS	23%	NS
		3m	0.308	8.74	90.952	25.17	09.622	PL	7%	NS
19.	Krishi Nagar	2m	0.618	17.709	81.673	52.1	35.11	NS	30%	NS
		3m	1.252	15.421	83.327	46.78	19.01	NS	31%	NS
20.	Suhagi	2m	2.77	15.472	81.758	51.35	21.183	NS	42%	NS
		3m	0.904	15.056	84.04	56.2	31.839	NS	43%	NS

Interesting result is seen in the sample of Victoria 3m, here, criteria no 1 clearly groups it as potentially liquefiable while criteria no 2 again says that, further studies are required for the sample.

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